MODELING AND ANALYSIS OF ALGAL BLOOMS IN ARAS DAM BY ARTIFICIAL NEURAL NETWORK

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ABSTRACT. – Modeling and analysis of algal blooms in Aras Dam by artificial neural network. Man made practices have contributed to large-scale algal blooms that have caused serious ecological, aesthetic, water purification and water distribution problems. Aras Dam, which provides Arasful city with drinking water, has chronic algal blooms since 1990. This study addresses the use of artificial neural network (ANN) model to anticipate the chlorophyll-a concentration in water of dam reservoir. Operation tests carried out by collecting water samples from 5 stations and examined for physical quality parameters namely: water temperature, total suspended solids (TSS), biochemical oxygen demands (BOD), ortophosphate, total phosphorous and nitrate concentrations using standard methods. Chlorophyll-a was also checked separately in order to investigate the accuracy of the predicted results by ANN. The results showed that a network was highly accurate in predicting the Chl-a concentration. A good agreement between actual data and the ANN outputs for training was observed, indicating the validation of testing data sets. The initial results of the research indicate that the dam is enriched with nutrients (phosphorus and nitrogen). The Chl-a concentration that were predicted by the model were beyond the standard levels; indicating the possibility of eutrophication especially during fall season.

Keywords: Aras dam, Chlorophyll-a concentration, artificial neural network.

1. INTRODUCTION

Algae are a diverse group of aquatic plants containing chlorophyll and other photosynthetic pigments. Many are microscopic (often being single cells) but some can be large, including the large seaweeds. They grow as single cells or aggregations of colonies (Chorus I, Bartram,1999). Algae are amazingly diverse in size, shape and color. They include a variety of aquatic plants ranging from single- celled plants that are invisible to the naked eye to giant kelps that can grow up to 45 meters and weigh as much as a small tree (Graham et al.2004). Algae can be found on soil, beneath polar ice and in snow, but greatest numbers are found in the waters that cover 70 % of the earth's surface (Barnard and Andrews. 2006). It is the chlorophyll and other photosynthetic pigments that give algae their characteristic colors. Most people have seen piles of green or brownish weed stranded along an estuary or ocean shoreline, or noticed lake waters turn a murky 'pea soup' green color (Beeton. 1971). Photosynthesis is the conversion of carbon dioxide and water to carbohydrates using light energy. Oxygen is produced in the process.

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Eutrophication is the process whereby water bodies become enriched by nutrients (Phosphorus and Nitrogen) from both external and internal sources. It is considered as one of the most pressing environmental problems in both the developed and the developing countries (Carmichael and Biggs. 1997). Prediction of Chl-a within dams' environment is a suitable application of ANNs.

Table. 1. ***Neural network architecture and Input variables for various ANN model***

Number of scenario	Input variables	Output variables
1	Spring,PO_4,Temperature, NO_3, DO, Chl-a, Phosphate, TSS	Chl-a
2	Summer, PO_4,Temperature,NO_3,DO, Chl-a, Phosphate, TSS	Chl-a
3	Fall, PO_4,Temperature,NO_3,DO, Chl-a, Phosphate, TSS	Chl-a
4	Winter, PO_4,Temperature,NO_3,DO, Chl-a, Phosphate, TSS	Chl-a

This predictive tool provides opportunities for proactive rather than reactive management regimes with regard to mitigating the effects of dams' algal blooms. The purpose of this study is to predict Chl-a concentration by the use of NNA model and compare the results obtained by the actual Chl-a concentration measured by HPLC.

2. CASE STUDY OF ARAS DAM

The dam withholds a reservoir of 1.35 cubic kilometres with a surface area of 145 square kilometers. Since opening, the reservoir has provided irrigation water for 400,000 hectares (990,000 acres) of arable land in Azerbaijan and Iran, including about 60,000 hectares (150,000 acres) in Dasht-e Moghan area.

The dam has been experiencing algal problems since 1985. Levels of up to 450,000 cells/mL of cyanobacteria (mainly *Anabaena* and *Microcystis*) have been recorded in the dam. When the level of blue-green algae in the dam exceeds 25,000 cells/mL the dam is closed to recreational users. Department of Public Works and Services reported that the existing dam storage is on the border of being eutrophic i.e. susceptible to blue green algal growth with associated impacts on water quality.

Outbreak of blue green algae depends on the interaction of a wide range of biophysical processes and socio-economic factors such as nutrients, temperature, light, dissolved oxygen, aquatic ecosystem balance, land use and catchment management. From management point of view, prediction of eutriphication based on the available influencing factors is essential. Different samples were taken from

6 sampling points a total number of 144 samples were collected and analyzed for each parameters' amounts.

Fig. 1. ***Map of the six sampling stations***

3. INPUT VARIABLES

Selection of network parameters is undertaken through iterative testing of a number of network scenarios which contain a variety of input variables. The aim is to provide a robust model based on the lowest number of input variables, with a modest data requirement. Inputs considered for the ANN included nutrients, Chl-a, water temperature, alkalinity and salinity. Water temperature is also known as an important variable controlling algal biomass and subsequent bloom conditions. Temperature is considered for the inputs of the model with consideration given to diurnal and seasonal patterns. These patterns showed that the warmest diurnal temperatures occurred during the afternoon and that the warmest seasonal temperatures are associated with summer months. These warm periods are mostly associated with the highest Chl-a measurements. Therefore, variables considered to be most influential for the prediction of algal blooms included: time lagged Chl-a, water temperature, total suspended solids (TSS), biochemical oxygen demands (BOD), ortophosphate, total phosphorous and nitrate concentrations (Table 1).

4. MODEL PREDECTION AND STATYSTICAL ANALYSIS

Figures 2 (a-d) show the measured and simulated concentration of Chl-a obtained by ANN model analysis in different seasons. As shown in the figures, the Concentration of chlorophyll–a reduced as approaching towards the colder months due to the lower amount of sunlight available, the lower water temperature and limited nutrient concentration. The *RMSE*, and R^2 between actual and predicted

chl-a concentration obtained from training and testing data set of ANN models were averaged, and the results are provided in Table 2. A low RMSE values (table 2) indicate that the ANN model predictions are closely matching with the actual observations when compared to the ANN model predictions. Further, the 'R^2' values for the ANN models are greater than (0.99). It shows that ANN model predictions are accurate. Maximum recorded chlorophyll a ranged among systems from 0.2-0.47 mg/L. The largest proportion of maxima occurred in Summer (60%), followed by Spring, fall and winter. It is suggested that, chlorophyll-a concentrations should be kept below 5 ug/L in reservoirs used for drinking water and below 20 mg/L for recreational places (Falconer et al.1999; Federal Register, 1998). These maxima generally are in relation with the most stable flow conditions in dam steams. Temporal and spatial variability in abundance of Chl-a were noticed in mid-summer when surface water nutrients were higher as verified in the figures. A number of studies supported that the bloom might occur during spring, or fall or even winter. During the bloom period, the population of algae was above the drinking water protection level i.e. 1000-2000 cells/mL of toxic algae. Later chl-a declined probably due to the cold water inflow to the dam. Differences in the seasonal distribution of Chl-a might be expected to introduce variability for maximum algae cells because seasonal variations in light levels and temperature can strongly influence growth rates. Indeed, higher growth rates did occur during summer in a subset of the streams. Most of the sampling time the values were beyond the standard range (0.005-0.025 mg/L) reported in the literature for productive waters (Donald et al.2002).

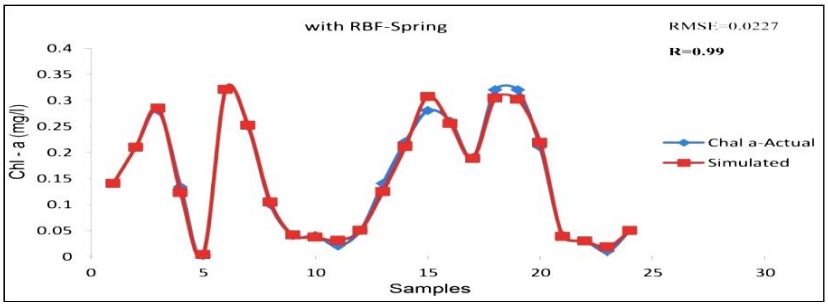
Table. 2. ***Range of error analysis of ANN model***

Scenario No	RMSE	R^2
1	0.0227	0.9902
2	0.0131	0.9903
3	0.0197	0.9917
4	0.0102	0.9901

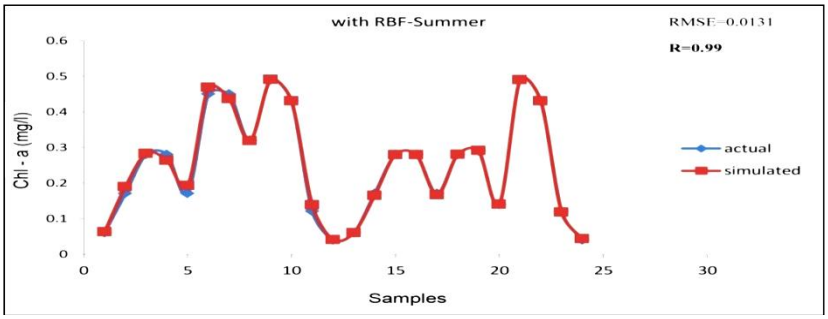
5. CONCLUSIONS

In this research, ANN was used for prediction of Chl-a concentration in the water of the Aras dam (Iran). The identified models were trained, validated and tested on Chl-a concentration measured in 2013. The network designs including 7 input variables, and 1 output neuron were found to be suitable for this study. We propose the neural network as effective tool for the computation of reservoir water quality and it could also be used in other areas to improve the understanding of reservoir pollution indexes. Excellent agreement between experimental data and ANN results were indicated. The ANN can be seen as a powerful predictive alternative to traditional modeling techniques.

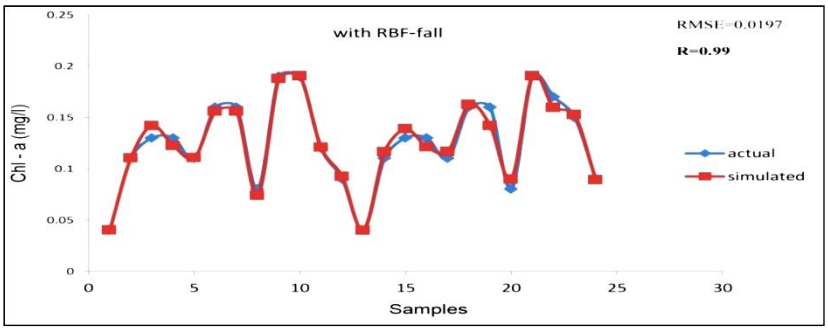
(a)



(b)



(c)



(d)

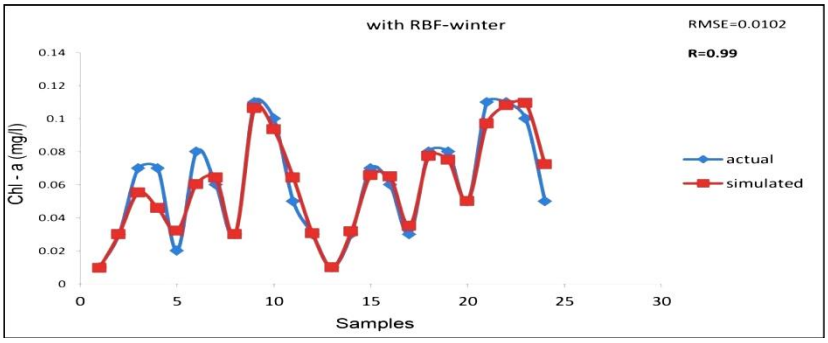


Fig. 2. ***Comparing ANN output and experimental data for Chl-a concentration in Spring(a), Summer(b), Fall (C) and Winter (d)***

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